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Combining Human Visual System Models for Geographic Gaze Contingent Displays

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Abstract

We present a gaze-contingent display (GCD) in which we combine multiple models of the human visual system (HVS) to manage the visual level of detail (LOD). GCDs respond to the viewer's gaze in real time, rendering a space-variant visualization. We aim to measure the computational and perceptual benefits of the proposed HVS models in terms of data reduction and user experience. Specifically, we combine models of contrast sensitivity, color perception and depth of field; and customize our implementation for geographic imagery. We believe this research is relevant in all domains that use image interpretation.

Categories and Subject Descriptors (according to ACM CCS): H 1.2 [User/Machine Systems]: Human Factors-Human Information Processing, H 5.2 [User Interfaces]: Input devices and strategies, I.4 [Image Processing and Computer Vision]-Image displays

1. Introduction

Aerial and satellite imagery are used for a variety of tasks such as change detection, urban planning, emergency/rescue operations, and damage assessments. In such tasks, a viewer is expected to visually interpret a series of images. Collectively, such tasks are demanding on computational resources as well as humans. With the availability of new sensors and devices data size issues have become even more pronounced [MB13, SBSS14]. Therefore, image compression, visualization and level of detail management efforts remain relevant [YW09]. However, despite their promise, to the best of our knowledge, no studies attempt to bring together HVS models into a combined solution [BÇS12].

A GCD obtains the gaze coordinates from an eye tracker and removes the perceptually irrelevant detail in the periphery. In this paper, we propose a GCD test bed where we apply three main visual perception models stand-alone and in combination to better understand the potential of HVS-inspired visualization paradigms in geographic information science domain.

2. Implementation

The first model we included in our test bed is known as *foveation* which is shown to be a useful technique for reducing image resolution from the periphery [GP98]. Many of the foveated GCDs use a contrast sensitivity function (CSF) that accounts for the level of detail change in 2D visual filed. The second model we employed uses the color mask presented in [DBS*09], which degrades the chromaticity from POI to periphery in accordance with the HVS. The depth of field (DOF) simulation proposed in [Rok96] is the third model in our test bed. Besides the computational benefits, HVS-inspired LOD management approaches have been suggested to be *perceptually lossless* by various authors [Bc11,HM97]. Separate implementations of CSF, color and DOF models have been proposed; however, a combination of these is rarely found. Below we describe our implementation where we combine these three models and allow adjusting relevant spatial parameters.

For real-time gaze contingent rendering, we have used OpenGL and implemented our models in fragment shaders (GLSL language). The system works with mouse as well as gaze input through eye tracking. In the final stage of rendering pipeline (rasterization in fragment shaders), a mipmap mechanism was employed for the gaze contingent LOD adjustment. For each pixel of the uniform resolution image, a new LOD was calculated (mipmaped) with respect to a weighted-Euclidean-distance between this pixel and the current point of interest (POI). For the foveation model, the weighting was decided based on the CSF. For the DOF simulation, we used a digital elevation model (DEM: the third image in Figure 1). For foveation and DOF simulation, image resolution is reduced by the exponents of 2. This is illustrated in the second and fourth images respectively in Figure 1. The change in resolution is represented with shades of gray starting with white (original resolution). For the color model, the weighting was based on a mask which was conveyed to the fragment shader as a second raster image (the fifth image in Figure 1). Color reduction is represented with the shades of orange (full color, fifth image in Figure 1). Our combined model first employs the CSF and reduces the resolution in 2D space, then the DOF model to further reduce resolution in 3D space. If you compare the second and fourth images in Figure 1 you can see the additional resolution degradation coming from DOF. Finally the color model is used to adjusts the chromacity of each pixel. This implementation served as a test bed for computational and perceptual experiments.

3. Results and Discussion

In computational validation, we studied the changes in the compression ratio as a function of our models. Depending on the POI location, our combined model leads to 2 to 10 times better compression ratios than the uniform resolution images. Furthermore, in a user study with 12 participants, we measured efficiency (task time) and effectiveness (accuracy) of the participants as they completed visual search tasks. The results showed that about 70% of the participants did not notice any visual artifacts and efficiency and effectiveness were not harmed by the GCDs.

At this point, both the computational validation experiments and the user study results indicate the HVS-based data reduction solutions are competitive, and encourages further research. Furthermore, these experiments demonstrate that our test bed is a useful tool in gaining new knowledge on computational and user performance with the GCD paradigms.

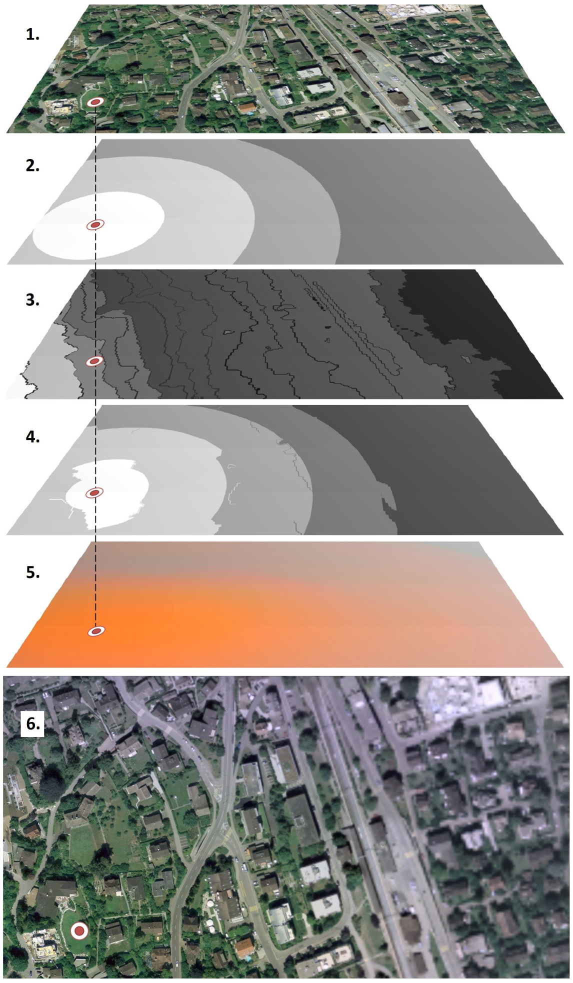

Figure 1: *Top to down: 1) Uniform resolution input 2) CSF based foveation 3) DEM 4) DOF simulation 5) Color mask and 6) Output image of the combined model. POI is located on the lower left and marked by a red dot. Image courtesy: © 2014 swisstopo (BA14108)*

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